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NWSC/CR/RDTR-34

PHOTOMETRIC AND NEAR INFRARED RADIOMETRIC MEASUREMENT SYSTEMS

NAVAL WEAPONS SUPPORT CENTER
APPLIED SCIENCES DEPARTMENT
CRANE, INDIANA 47522

30 August 1976

FINAL REPORT for Period 30 September 1974 to 30 June 1976

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Prepared for
COMMANDER
NAVAL AIR SYSTEMS COMMAND
WASHINGTON, D. C. 20361

Submitted

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Radiometry	Illuminating Flare
Radiation	Near Infrared
Photometer	Emission
	Detector

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the details of calibration, operation, and construction of a photometric, and a 0.73-0.97 μm (micrometers) near infrared radiometric measurement system, both constructed at NAVWPNSUPPCEN Crane for measurements of flare plume candlepower and radiant intensities, respectively.

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INTRODUCTION

In the improvement of existing flares and in the development of new flare concepts, it is necessary to measure candlepower and near infrared radiation. This report describes the details of calibration, operation, and construction of a photometric measurement system, and a 0.73-0.97 μm near infrared radiometric measurement system, both constructed at NAVWPNSUPPCEN Crane. The block diagram (Figure 1) is the same for both systems. The report describes each system separately. The description of each system is divided into two sections: (a) calibration and operation; and (b) construction details.

PHOTOMETER SYSTEM

Calibration and Operation

The photometer, details of which are described in the Construction Details section of this section, is calibrated against NBS Standard Lamp No. 9789, 1000 watt tungsten filament lamp[1] rated at 1070 candlepower. An optical bench is used and the lamp is properly shielded. We use the relationship

$$\frac{1070}{D^2} = E \qquad (1)$$

where E is the calculated illuminance in footcandles, and D is the distance in feet between the photometer and the standard lamp. For each distance, the irradiance E is calculated using equation (1) and plotted against the observed voltage at that distance. See Figure 2. The luminous intensity (candlepower), in candles, is calculated for a flare according to

$$I(cd) = E \cdot D^2 \qquad (2)$$

where E is the illuminance in foot candles, as determined from the observed voltage by using the calibration curve, and D is the distance in feet between the photometer and the flare. If the approximate candlepower of a flare is known beforehand, the photometer-to-flare distance is adjusted to keep the output in the linear region of operation.

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[1]General Electric Co., Cleveland, Ohio.

The output is recorded on a Moseley[2] strip chart recorder, and can be integrated as well.

Construction Details

The photometer system and the radiometer systems were built on printed circuit boards for easy component replacement and troubleshooting. The systems use all solid state circuitry and precision components.

The photometer system uses a Weston 856 photocell[3] corrected for eye response. An opal glass filter was inserted over the face of the photocell for uniform distribution of light. The field of view is ±12.5°.

The photometer detector/opal glass combination is mounted in a separate housing from the amplifier and the output signal is fed to an amplifier circuit through a coaxial cable. The input amplifier for the detector is also mounted on a printed circuit board in a precision current to voltage amplifying mode. The amplifier is a Burr Brown[4] 3341/15C inverting field effect transistorized line driving operational amplifier. This amplifier has an extremely wide bandwidth with fast slewing and settling characteristics, along with high gain accuracy and linearity. This amplifier is designed to withstand input voltages as high as the supply voltage without damage. The output stage is internally current limited to withstand short-circuit to ground conditions.

The feedback resistor is a precision 10 turn variable resistor to give a linear 0 to 5 volts output. The output of this amplifier is then coupled to a BNC connector for input to the recorder or integrator.

Figure 3b and 3c show the electronic schematics.

The Model P2.15.300 power supply[5] features dual ±15VDC output with up to 0.01% regulation, automatic short circuit protection, and is encapsulated with hermetically sealed components and tantalum capacitors for full rated operation through +85°C.

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[2]Hewlett-Packard, Inc., Palo Alto, California.

[3]Weston, Inc., Newark, New Jersey.

[4]Burr-Brown Research Corporation, Tucson, Arizona.

[5]Semiconductor Circuits Inc., Haverhill, Massachusetts.

The power supply is identical in the photometric and near infrared system. See Figure 4 for a schematic.

NEAR INFRARED (0.73-0.97 μm) SYSTEM

Calibration and Operation

The total relative system response (filter and detector) is shown in Figure 5. The wavelengths 0.73 and 0.97 μm were chosen since they are the points at which the relative response has fallen off to 0.5.

The equations regarding the calibration and operation of the radiometer are as follows:

$$V = c \cdot A \cdot R^{-2} \int N(\lambda) \cdot s(\lambda) \cdot \tau(\lambda) \cdot \tau_a(R,\lambda) d\lambda \qquad (3)$$

where

- V is the volts observed on the meter or chart recorder
- c is a constant, in $V/W \cdot cm^{-2}$
- A is the area in cm^2 of the blackbody source aperture
- R is the source-to-detector distance, in cm
- $N(\lambda)$ is the known radiance of a blackbody, in $W \cdot cm^{-2} \cdot sr^{-1} \cdot \mu m^{-1}$
- $s(\lambda)$ is the (dimensionless) relative spectral response of the detector
- $\tau(\lambda)$ is the (dimensionless) transmittance of the filter
- $\tau_a(R,\lambda)$ is the (dimensionless) transmittance due to atmospheric constituents.

In the spectral region 0.73-0.97 μm, $\tau_a \approx 1$. Therefore,

$$V = c \cdot A \cdot R^{-2} \int N(\lambda) \cdot s(\lambda) \cdot \tau(\lambda) d\lambda \qquad (4)$$

Since $N(\lambda)A = J(\lambda)$, the radiant intensity in $W \cdot sr^{-1}$, we can write

$$V = c \cdot R^{-2} \int J(\lambda) \cdot s(\lambda) \cdot \tau(\lambda) d\lambda. \qquad (5)$$

Calibration in this spectral region consists of placing the radiometer on an optical rail at a series of distances from a properly shielded and powered NBS-traceable lamp, of known spectral radiant intensity $J(\lambda)$, and recording the voltages obtained. Plotting V against R^{-2} will allow c to be calculated in $V/W \cdot cm^{-2}$. Figure 6 shows the results of a calibration, performed with a 1000 watt tungsten-halogen lamp (EG&G standard lamp serial number A163A, and their calibration test number 107019).[6]

In order to determine the $W \cdot sr^{-1}$ from a flare, (5) is used, except that $J(\lambda)$ is now the unknown instead of c. If we assume that $J(\lambda)$ doesn't vary much in the 0.73-0.97 µm interval, then it can be taken out of the integral.

$$V = c \cdot R^{-2} \cdot J' \int s(\lambda) \cdot \tau(\lambda) d\lambda \qquad (6)$$

where

$$J' = \frac{J(\lambda) d\lambda}{\Delta\lambda} \quad . \qquad (7)$$

Then

$$J' = \frac{V}{c \cdot R^{-2} \int s(\lambda) \cdot \tau(\lambda) d\lambda} \text{ , } W \cdot sr^{-1} \cdot \mu m^{-1} \quad . \qquad (8)$$

Finally

$$J_{BAND} = J'\Delta\lambda = J'(0.234), \ W \cdot sr^{-1} \qquad (9)$$

Construction Details

The radiometer system uses a PIN-10D silicon photodiode[7] responding from about 0.35 to 1.1 µm. A Corning 1-64 and 2-58 filter combination[8] was selected to limit system response to the near infrared. The field of view is ±12.5°.

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[6] EG&G, Electro-Optics Division, Salem, Massachusetts.

[7] United Detector Technology, Inc., Santa Monica, California.

[8] Corning Glass Works, Corning, New York.

The output signal is fed to the amplifier circuit through a coaxial cable.

The input amplifier for the detector is mounted on a printed circuit board, in a precision current to voltage amplifying mode. The amplifier is an Intech A157 F.E.T. input operational amplifier.[a] This amplifier has wideband, fast response characteristics and provides stable operation with capacitive loads up to 1000 pfd. The feedback resistor is a handpicked precision 10 KΩ resistor to give a linear voltage output from 0-10VDC. The output of the amplifier is then coupled to a BNC connector for input to the recorder or integrator.

See Figure 3a for a schematic.

The power supply has been described in Construction Details in the Photometer System section.

[a]Intech Inc.,Santa Clara, California.

PARTS LIST

Designation	Catalog Number	Source
PS-1	P2.15.300	Semiconductor Circuits, Inc., Haverhill, MA
F-1	AGC 1/2	Buss, fuses, St. Louis, MO
LS-1	36N2311	Allied Electronics, Elgin, IL
S-1	5222S	J.B.T. Instruments, Inc., New Haven, CT
Fuse Holder	HJM-H	Buss Fuses, St. Louis, MO
DT-1	856	Doystrom Inc., Newark, NJ
DT-2, DT-3	PIN-10D	United Detector Inc.,Santa Monica, CA
Filter 1-64	1-64	Corning Glass Works, Corning, NY
Filter 2-58	2-58	Corning Glass Works, Corning, NY
Opal Glass	2149	Edmund Scientific Co., Barrington, NJ
B.N.C. Connector	UG254A/U	Amphenol Connector Div., Broadview, IL
C-1	CD7FD151J	Cornell-Dubilier Electronics Div., Newark, NJ
C-2, C-3	CD6CD100K	Cornell-Dubilier Electronics Div., Newark, NJ
R-1	RN55D1002F	Allied Electronics, Elgin, IL
R-2	3359P1K	Bourns, Inc., Riverside, CA
R-3, R-4	224P25K	Bourns, Inc., Riverside, CA
A-1	A-157	Intech Inc., Santa Clara, CA
A-2, A-3	3341/15C	Burr-Brown Research Corp., Tucson, AZ

BLOCK DIAGRAM

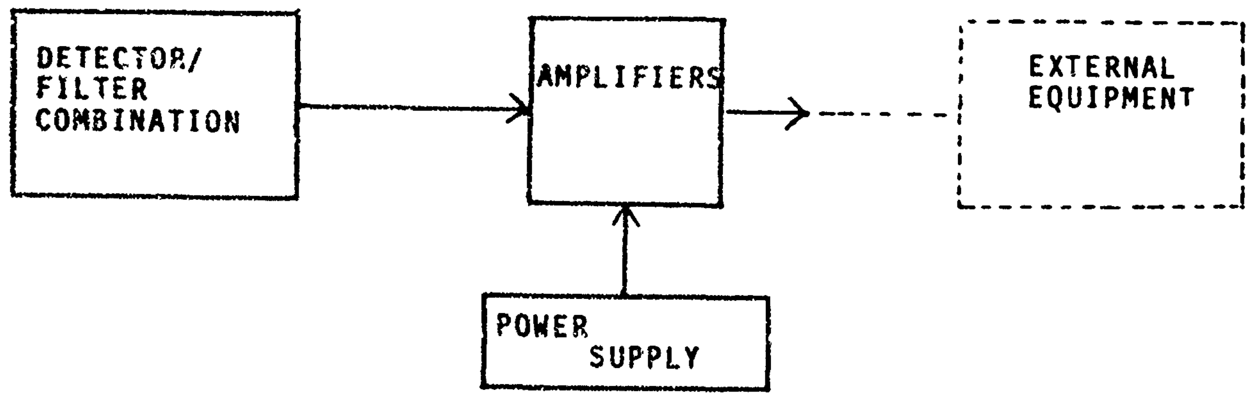

Figure 1. Block Diagram for Photometric and Near Infrared Radiometric Systems

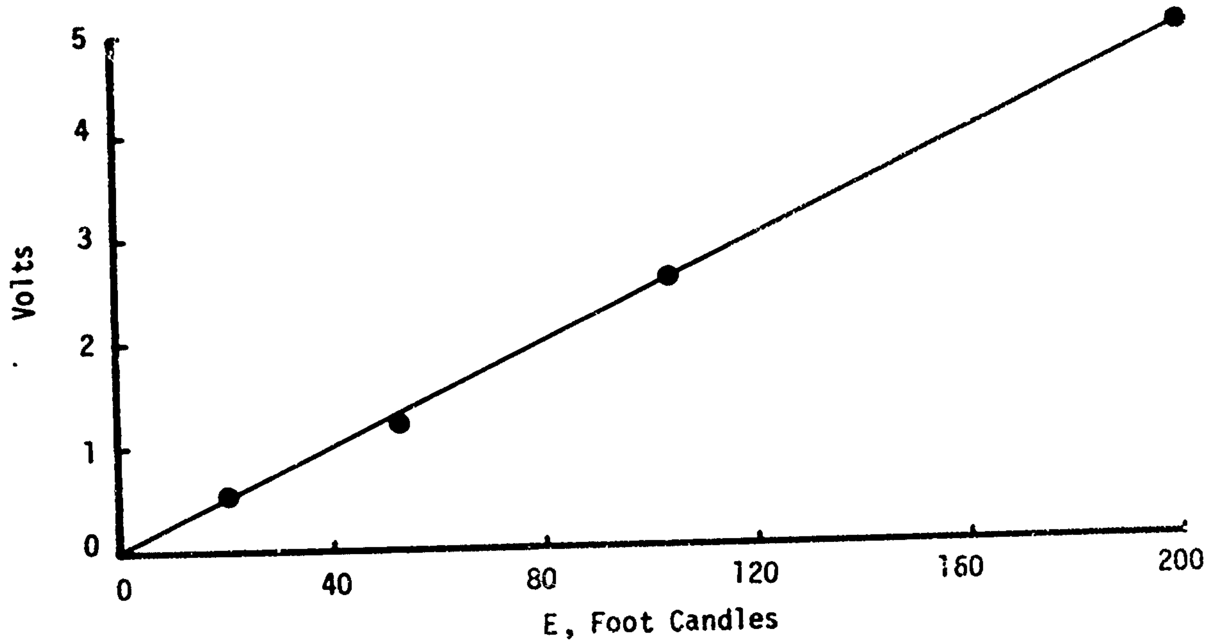

Figure 2. Calibration Curve for the Photometer

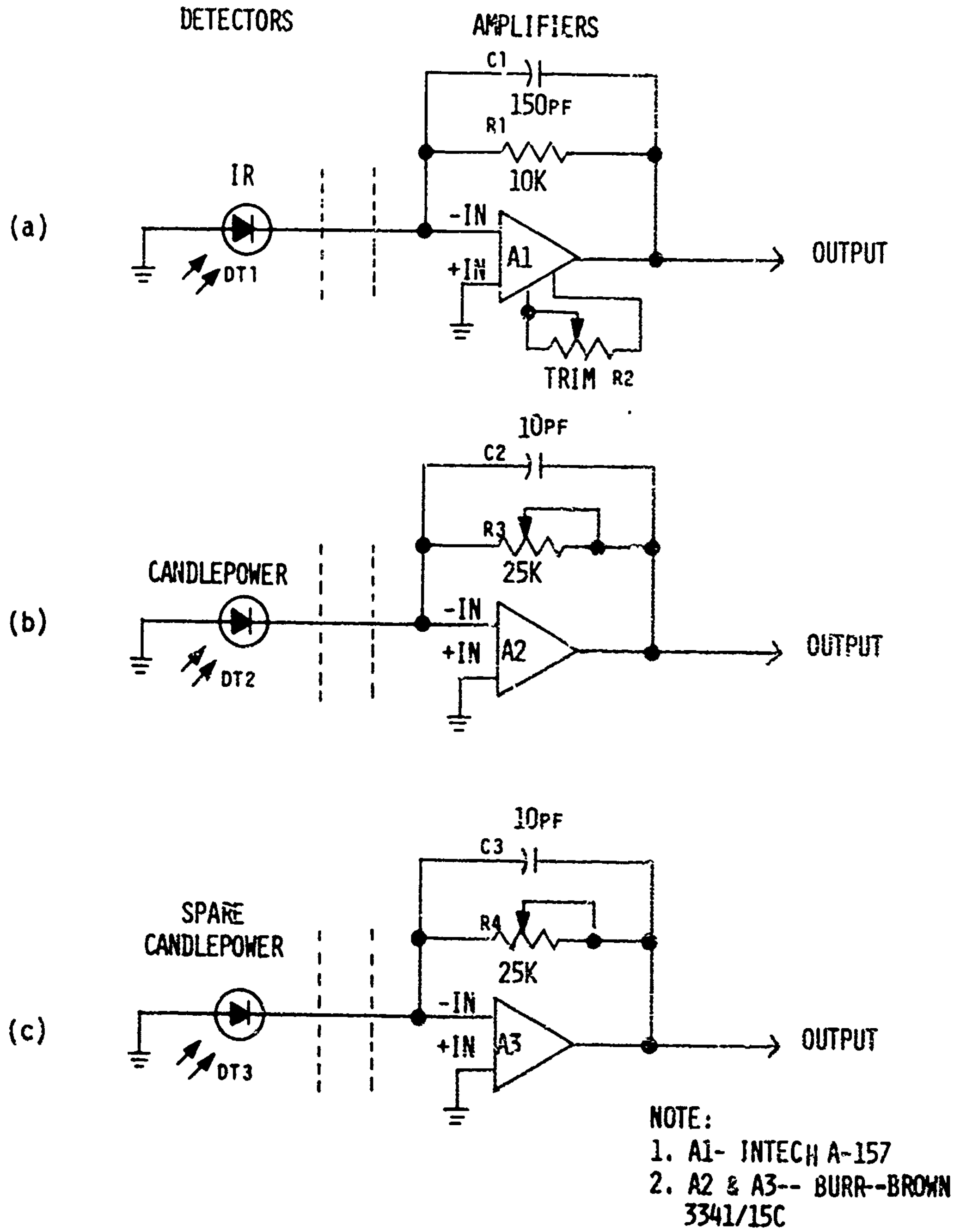

Figure 3. Detector Circuits for Near Infrared Radiation (a), and Visible Radiation (b) and (c).

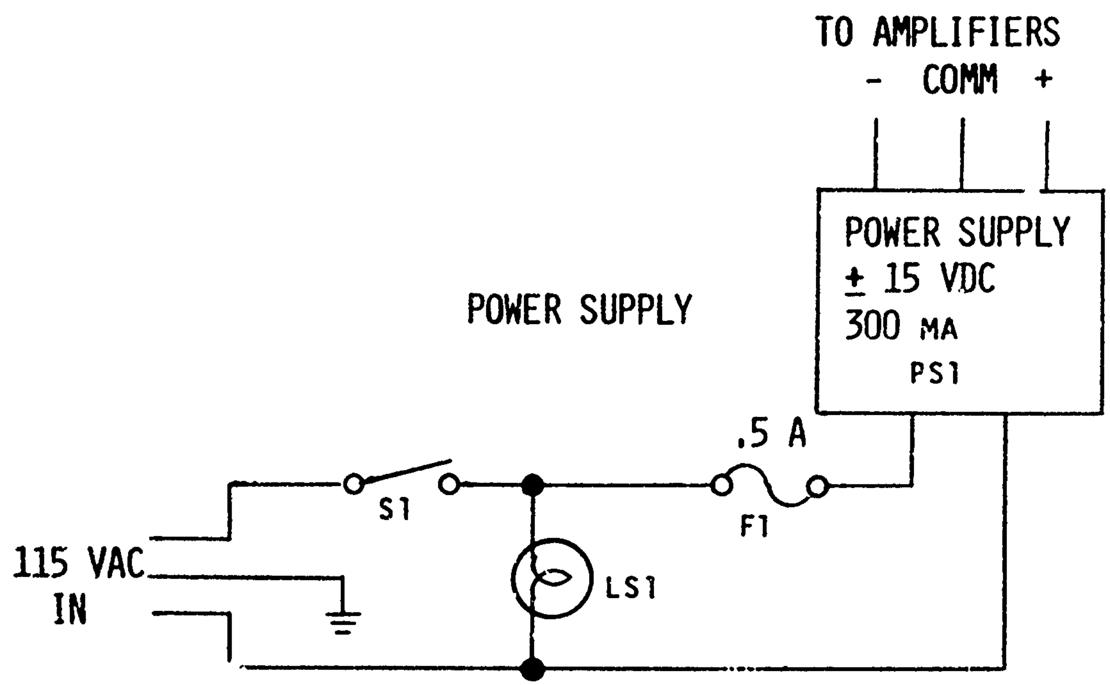

Figure 4. Power Supply for Both Photometric and Near Infrared Radiometric Systems

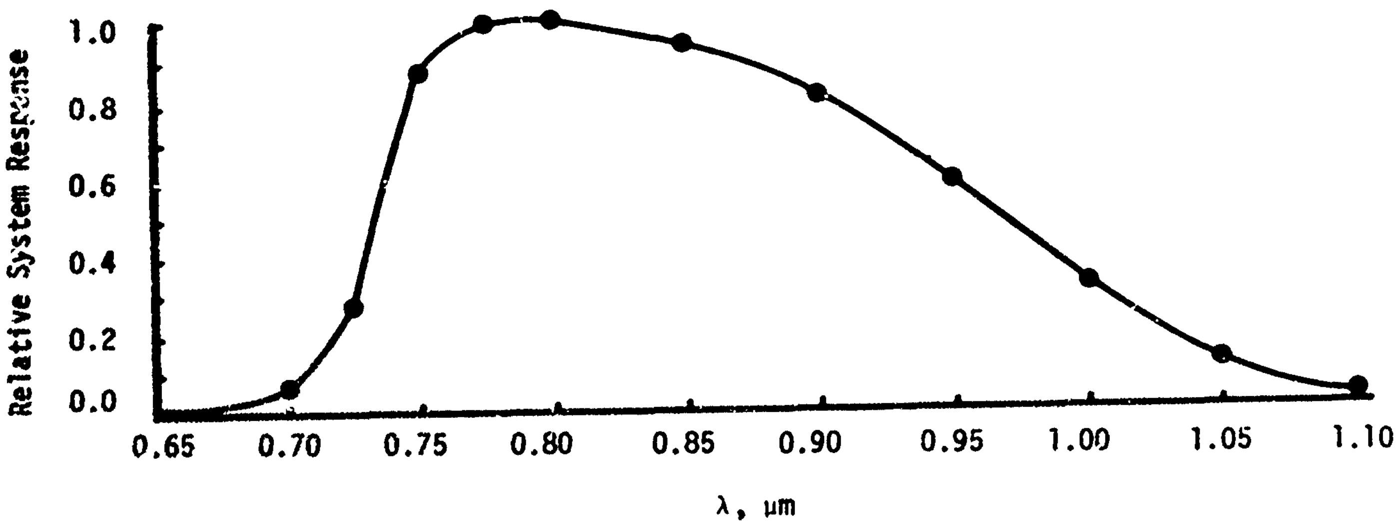

Figure 5. Relative System Response for the 0.73-0.97 μm Radiometer. This curve results from multiplying the detector response by the filter response and normalizing to 1.0.

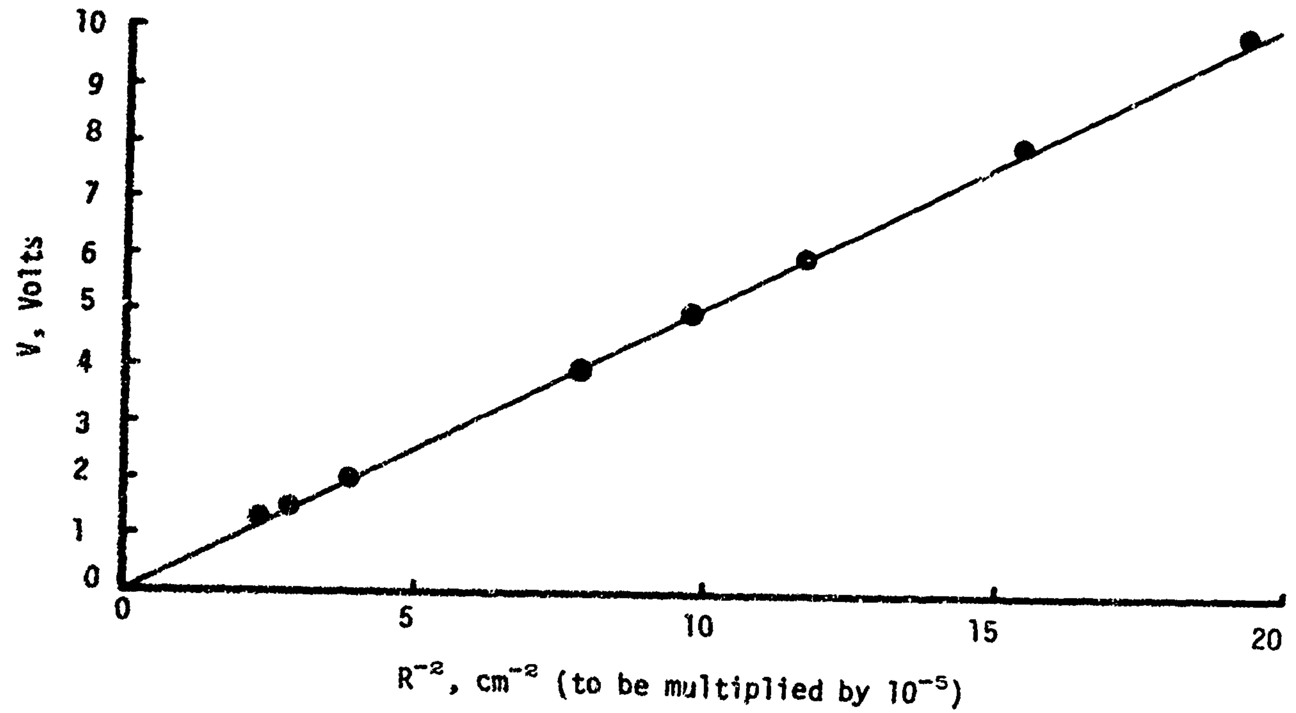

Figure 6. Calibration Curve for the 0.73-0.97 μm Radiometer

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